

## **The Nature of Science in The Next Generation Science Standards**

Scientists and science teachers agree that science is a way of explaining the natural world. In common parlance, science is both a set of practices and an accumulation of knowledge. An essential part of science education must include developing both the abilities and knowledge of the practices and the science concepts that are foundational to specific disciplines. Further, students should develop an understanding of the enterprise of science as a whole. This final statement establishes connections to the nature of science as a domain of learning outcomes for K–12 science education. The Next Generation Science Standards (NGSS) offer an opportunity to significantly impact science education. The purpose of this paper is to address the importance of understanding the Nature of Science and how students can build that knowledge through the NGSS.

### **The NRC Framework**

*The Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012) acknowledges the importance of the nature of science in the statement “... there is a strong consensus about characteristics of the scientific enterprise that should be understood by an educated citizen” (NRC, 2012, page 78). The *Framework* continues with reflections on the practices of science and returns to the nature of science in the following statement. “Epistemic knowledge is knowledge of the constructs and values that are intrinsic to science. Students need to understand what is meant, for example, by an observation, a hypothesis, an inference, a model, a theory, or a claim and be able to distinguish among them” (NCR, 2012, page 79). This quotation presents a series of concepts important to understanding the nature of science as a complement to the practices involved with activities such as investigations, field studies, and experiments.

This discussion leads to several questions. First, what should students understand about the nature of science? Second, what elements of the *Framework* present opportunities for teaching and learning about the nature of science? Third, are there any additions to the fundamental components—practices, crosscutting concepts, core disciplinary ideas—that would contribute to students’ developing a deeper and broader understanding of the nature of science? The NGSS are being developed based on the *Framework*, therefore, it will be important to have an understanding of how the nature of science can be represented through the dimensions described in the *Framework*.

### **Science Practices and Crosscutting Concepts**

Let us begin by examining the science practices and crosscutting concepts for connections between the fundamentals of doing scientific investigations and a basis for understanding the scientific enterprise.

Although one could propose all of the practices as essential for understanding the nature of science, four practices seem fundamental to understanding the nature of science. Those practices are:

- Developing and using models,
- Analyzing and interpreting data,
- Constructing explanations, and
- Engaging in argument from evidence.

From the crosscutting concepts one can use the following as complementary components to the proposed practices the combination establishes a procedural and conceptual a bridge to the nature of science.

- Patterns
- Cause and Effect: Mechanisms and Explanation
- Systems and System Models

### **Nature of Science: A Perspective**

It seems clear that instruction that centers on the integration of practices, core disciplinary ideas, and crosscutting concepts could set the stage for teaching and learning about the nature of science. This said, learning about the nature of science requires more than engaging in activities and conducting investigations.

When the three dimensions of the science standards are combined, one can ask: What is central to the intersection of the practices, core ideas, and crosscutting concepts? Or, what is the relationship among the three basic elements of *The Framework for K–12 Science Education*? Humans have a need to explain the world around them. In some cases, the need originates in potential dangers, sometimes it is a curiosity, and in other cases the promise of a better life. Science is the pursuit of explanations of the natural world. As a foundation for K–12 science education, the issue is explaining the natural world and especially the formation of adequate, evidence-based scientific explanations. To be clear, this sort of explanation should not be confused with how students engage in the practice of constructing explanations. Obviously, students in K–12 are not likely to construct new explanations of the natural world; they can understand and engage in the process scientists use to acquire scientific knowledge.

Now, the science teachers' question—How do I put the elements of practices and crosscutting concepts together to help students understand the nature of science? Suppose students observe the moon's movements in the sky, changes in seasons, phase changes in water, or life cycles of organisms. One can have them observe patterns and have them propose explanations of cause-effect. Then, have the students develop a model of the system based on their proposed explanation. Next, they design an investigation to test the model. In designing the investigation they have to gather data and analyze data. Next they participate in the practice of constructing an explanation using an evidence-based argument. A science teacher may also probe students' understanding of possible mechanisms for the phenomena they observe.

### **Using Examples from the History of Science**

It is one thing to develop the practices and crosscutting concepts in the context of core disciplinary ideas. It is another aim to develop an understanding of the nature of science within those contexts. The use of case studies from the history of science provides contexts to develop students' understanding of the nature of science. For example, in the upper grades case studies

on the following topics might be used to broaden and deepen understanding about nature of science.

- Copernican Resolution
- Newtonian Mechanics
- Lyell's Study of Patterns of Rocks and Fossils
- Progression from Continental Drift to Plate Tectonics
- Lavoisier/Dalton and Atomic Structure
- Darwin Theory of Biological Evolution and the Modern Synthesis
- Pasteur and the Germ Theory of Disease
- James Watson and Frances Crick and The Molecular Model of Genetics

These explanations could be supplemented with other cases from history. The point is providing an instructional context that bridges the practices and nature of science through understanding the role of systems models, patterns, cause and effect, the analysis and interpretations of data, the importance of evidence with scientific arguments, and the construction of scientific explanations of the natural world. In the case studies these understandings of the nature of explanations are placed in the larger context of scientific models, laws, and theories.

### **A Rationale and Research**

Addressing the need for students to understand both the concepts and practices of science and the nature of science is not new in American education. The writings of James B. Conant, in the 1940s and 50s, for example, argue for a greater understanding of science by citizens (Conant, 1947). In *Science and Common Senses* (Conant, 1951), discusses the “bewilderment of laymen” when it comes to understanding what science can and cannot accomplish both in the detailed context of investigations and larger perspective of understanding science. Here is a statement by Conant “...the remedy does not lie in a greater dissemination of scientific information among nonscientists. Being well informed about science is not the same thing as understanding science, though the two propositions are not antithetical. What is needed is methods for importing some knowledge of the tactics and strategy of science to those who are not scientists” (Conant, 1951, page 4). In the context of this discussion tactics are analogue to practices and the strategies are analogue to the nature of scientific explanations.

The present discussion recommends the aforementioned “tactics of science practices and crosscutting concepts” to develop students’ understanding of the larger strategies of the scientific enterprise—the nature of scientific explanation. One should note that Conant and colleagues went on to develop the *Harvard Cases in History of Science*, a historical approach to understanding science. An extension of the nature of science as a learning goal for recording education soon followed the original work at Harvard. In the late 1950s, Leo Klopfer adapted the *Harvard Cases* for use in high schools (Klopfer & Cooley, 1963). Work on the nature of science has continued with lines of research by Lederman (1992), Lederman and colleagues (Lederman et al, 2002d; 2002b), and Duschl (1990; 2000; 2008). One should note that one aspect of this research base addresses the teaching of nature of science (see, e.g. Lederman and Lederman, 2004; Flick and Lederman, 2004; Duschl, 1990; McComus, 1998; Osborne et al, 2003; Duschl & Grandy, 2008).

Further support for teaching about the nature of science can be seen in 40 years of Position Statements from the National Science Teachers Association (NSTA). In the late 1980s, *Science For All Americans* (Rutherford & Ahlgren, 1989) and in the 1990s policy statement *Benchmark for Science Literacy* (AAAS, 1993) and *National Science Education Standards* (NRC, 1996) clearly set understanding the nature of science as learning outcomes for science education.

Recently, discussions of the (NRC, 2012) and implications for science teaching have provided background or instructional strategies that connect specific practices and the nature of scientific explanations (Duschl, 2012; Krajcik & Merritt, 2012; Reise, Berland, & Kenyon, 2012).

## **Conclusion**

This discussion addressed the challenge of including the nature of science in classrooms based on the Next Generation Science Standards. The approach centered on the intersection of science practices, core disciplinary ideas, and crosscutting concepts. The nature of the scientific explanations was proposed as the idea central to standards-based classrooms. Beginning with the practices, core ideas, and crosscutting concepts science teachers can progress to the regularities of laws, in importance of evidence, and the formulation of theories in science. With the addition of historical examples, the nature of scientific explanations assumes both a human face and is recognized as an ever-changing enterprise.

## References

- American Association for the Advancement of Science. (1993). *Benchmarks for Science Literacy*. New York: Oxford University Press.
- Conant, J. (1947). *On Understanding Science: A Historical Approach*. Cambridge, MA: Harvard University Press.
- Conant, J.B. (1951). *Science and Common Sense*. New Heaven: Yale University Press.
- Duschl, R. (2008). Science Education in 3-part Harmony: Balancing Conceptual, Epistemic, and Social Learning Goals. In J. Green, A. Luke, & G. Kelly, Eds., *Review of Research in Education*, V32. (pp. 268-291) Washington, DC: AERA.
- Duschl, R. (2000). Making the Nature of Science Explicit. In R. Millar, J. Leech & J. Osborne (Eds.) *Improving Science Education: The Contribution of research*. Philadelphia, PA USA: Open University Press.
- Duschl, R. (1990). *Restructuring Science Education: The Role of Theories and Their Importance*. New York: Teachers College Press.
- Duschl, R. & Grandy, R. (eds.) (2008). *Teaching Scientific Inquiry: Recommendations for Research and Implementation*. Rotterdam, Netherlands: Sense Publishers.
- Flick, L., & Lederman, M. (2004). *Scientific Inquiry and Nature of Science*. Boston, MA: Kluwer Academic Publishers.
- Klopfer, L. & Cooley, W. (1963). The History of Science Cases for High Schools in the Development of Student Understanding of Science and Scientists. *Journal of Research in Science Teaching*, 1(1), 33-47.
- Lederman, N., Abd-el-Khalick, F., Bell, R.L., & Schwartz, R.S. (2002). View of Nature of Science Questionnaire: Towards Valid and Meaningful Assessment of Learners' Conceptions of the Nature of Science. *Journal of Research in Science Teaching*, 39(6), 497-521.
- Lederman, N. & Lederman, J. (2004). Revising Instruction to Teach Nature of Science: Modifying Activities to Enhance Students' Understanding of Science. *The Science of Teacher*, November.
- Lederman, N.G. (1992). Students' and Teachers' Conceptions of the Nature of Science: A Review of the Research. *Journal of Research in Science Teaching*, 29(4), 331-359.
- McComus, W., Ed., (1998). *The Nature of Science in Science Education: Rationales and Strategies*. Dordrecht: Kluwer.
- National Research Council. (1996). *National Science Education Standards*. Washington, DC: The National Academy Press.
- National Research Council. (2012). *A Frameworkd for K-12 Science Education: Practices, Crosscutting Concepts, and Core ideas*. Washington, DC: The National Academy Press.
- Osborne, J.F., Ratcliffe, M., Collins, S., Millar, R., & Duschl, R. (2003). What 'Ideas about Science' should be taught in School Science? A Delphi Study of the 'Expert' Community. *Journal of Research in Science Teaching*, 40(7), 692-720.
- Rutherford, F.J., & Algren, A. (1989). *Science for All Americans*. New York: Oxford University Press, Inc.